ELSEVIER
CrossMark
Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering 81 (2014) 1139 – 1144
Procedia Engineering
www.elsevier.com/locate/procedia

11th International Conference on Technology of Plasticity, ICTP 2014, 19-24 October 2014, Nagoya Congress Center, Nagoya, Japan

Measurement of rollover in double-sided shearing using image processing and influence of clearance

Masahiro Sasada*, Taiki Togashi

Kanagawa University, Rokkakubashi 3-27-1, Kanagawa-ku, yokohama-shi,kanagawa-ken,221-8686, Japan

Abstract

The cut surface of sheared products is composed of the rollover, burnished surface, fractured surface and burr. It is important to clarify the relationship between the material flow and the formation of rollover to reduce rollover and obtain the desired rollover shape. Double-sided shearing with a counter punch was carried out using an experimental device. The deformation of the sheet material was observed through reinforced glass using a high-speed camera. Then, image processing was performed to investigate the material flow. Rollover was formed by material flow in the direction of the clearance and material flow in the lateral direction, which was confirmed experimentally using image processing. When the clearance is small, the material flow in the lateral direction affected on the rollover. In contrast, when the clearance is large, the material flow in the direction of clearance affected the rollover.

Selection and peer-review under responsibility of the Department of Materials Science and Engineering, Nagoya University

Keywords:Shearing; Rollover; Image processing

1. Introduction

Shearing has widely been used for many types of product because of its high productivity. However, the cut edge has rollover, a fractured surface, and burr due to shearing. The demand for reduced rollover and products with

* Corresponding author. Tel.:+ 81-45-481-5661; fax: + 81-45-491-7915.
E-mail address: sasadm01@kanagawa-u.ac.jp

1877-7058 © 2014 Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license
(http://creativecommons.org/licenses/by-nc-nd/3.0/).
Selection and peer-review under responsibility of the Department of Materials Science and Engineering, Nagoya University
doi:10.1016/j.proeng.2014.10.248

the desired rollover shape is increasing. It is important that the relationship between the material flow and the formation of rollover is clarified to reduce rollover and obtain the desired rollover shape. Jimma (1965) reported the relationship between the rollover and punch stroke for different clearances. Kondo (1988) explained the formation of rollover in shearing by the insufficiency of the material in the clearance between the punch and die. Ikushima et al. (1992) proposed a new punching method for shear droop-free shearing by the combination of coining using a knife-edge punch and conventional punching. Many useful studies on rollover have been reported. Moreover, many useful studies helping to clarify the material flow in shearing have been reported. Kasuga et al. (1977) investigated material deformation in the shearing process. Maeda and Aoki (1979) performed an experiment on the slip behaviour of materials to discuss the wear of shearing tools. Koga et al. (1992) proposed the remeshing visioplasticity method to investigate crack initiation in shearing. Takahashi and Aoki (1996) analyzed shearing by a visioplasticity method using image processing. Aoki and Takahashi (2003) reported a material flow analysis on the shearing process by applying the Fourier phase correlation method to analyze piercing and fine blanking. The occurrence of material flow in the lateral direction in shearing has been clarified. The purpose of this study is to investigate the influence of the clearance on rollover using image processing based on images taken during a shearing process. The influence of material flows in the lateral and clearance directions on rollover formation is also discussed in this report.

2. Experimental procedure

Double-sided shearing with a counter punch was carried out using the experimental device shown in Fig.1. To realize a plane strain state, the sheet material was placed between reinforced glass and a constraint plate during shearing. The sheet material used was aluminium (JIS A1100P-O) with a length of 39mm, a width of 12mm, and a thickness of 3mm. The reinforced glass had a length of 44mm, a width of 30mm, and a thickness of 10mm. The clearance was set to 1, 5, 10, or 15% of the sheet material thickness. The force of the counter punch was set to 1000N. The blank holder constrained the vertical displacement of the sheet material. The deformation of the sheet material was observed through the reinforced glass using a high-speed camera. The images were photographed by a high-speed CCD camera with 640×480 pixels during shearing. Then, the observed images were processed using software (Dipp-Motion Pro 2D) to investigate the material flow. The shearing force was measured by a strain-gage-type load cell. The displacement of the punch was measured by a displacement sensor. The shearing speed was set to 0.1mm/s.

3. Experimental results

3.1. Confirmation of measurement accuracy

First, the measurement accuracy of the image processing performed to investigate material flow was confirmed. When the punch was moved without the sheet material using the experimental equipment shown in Fig. 1, the

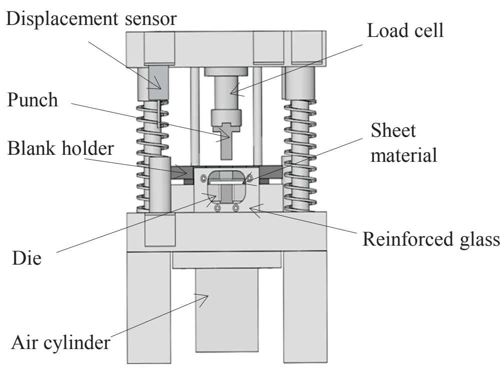

Fig. 1. Experimental apparatus.

displacement of the punch tip was measured by image processing. The displacement of the punch was also measured by a displacement sensor. The relationship between the displacement of the punch tip measured by image processing and that measured by displacement sensor is shown in Fig. 2. The measurement accuracy of image processing was found to be satisfactory for investigating the material flow.

3.2. The shape of cut edges obtained by shearing

The cut edges obtained by shearing are shown in Fig. 3. The relationship between the rollover height and the distance from the cutting edge of the punch is shown in Fig. 4. The rollover height obtained by shearing increased with increasing clearance. The relationship between the punch stroke and rollover height is shown in Fig. 5(a). In the initial shearing process, the increase in rollover height is approximately equal regardless of the clearance. The rollover height for a clearance of 1% hardly increased above *P*s=0.8 mm. On the other hand, the rollover height for a clearance of 15% increased from *P*s=0.8 mm to *P*s=2.0 mm. The relationship between the punch stroke and rollover width is shown in Fig. 5(b). The rollover width in the case of a large clearance was larger than that in the case of a small clearance.

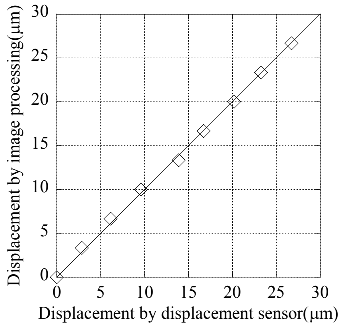

Fig. 2. Relationship between displacement measured by image processing and displacement measured by linear displacement sensor.

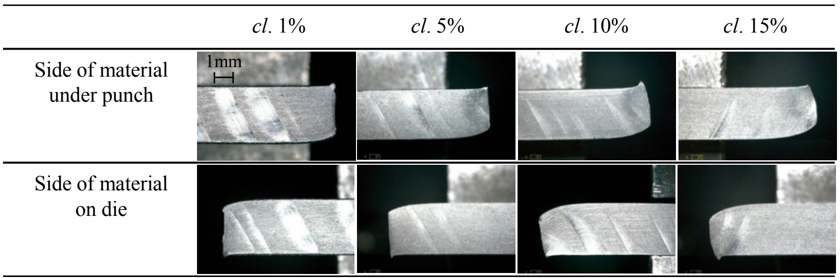

Fig. 3. Cross sectional views of sheet material.

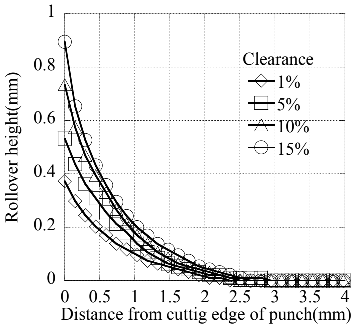

Fig. 4. Relationship between rollover height and distance from cutting edge of punch.

3.3. Material flows obtained by image processing

The material flows obtained by image processing when the punch stroke increased from 0.2mm to 0.3mm are shown in Fig. 6. The direction of material flows is signified by the direction of the arrows, and the dimensions of the material flows are signified by the color and length of the arrows. The material around the punch edge flows in the lateral direction and the clearance direction. The material flows when the punch stroke increased from 0.9mm to 1.0mm are shown in Fig. 7. The material flow in the lateral direction was small and the material continued to flow in the direction of clearance.

3.4. Relationship between material flow and rollover

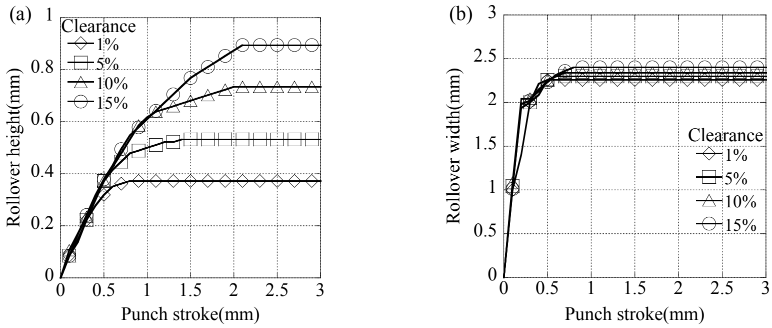

Fig. 5. Effect of clearance on rollover :(a)height;(b)width.

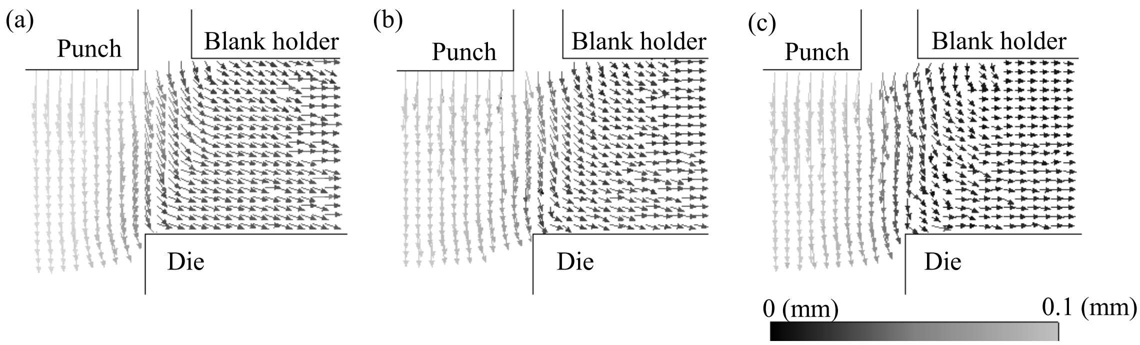

Fig. 6. Material flows obtained by image processing when the punch stroke increased from 0.2mm to0.3mm:(a)*Cl*.1%; (b)*Cl*.5%; (c)*Cl*.15%.

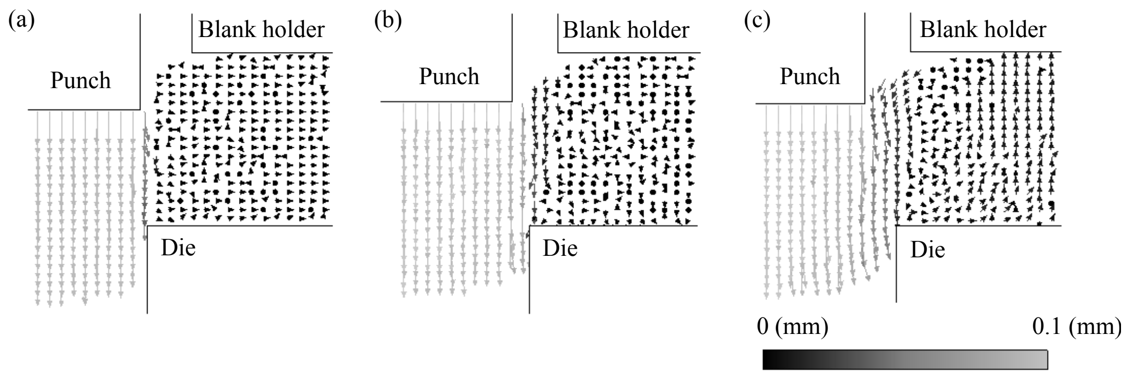

Fig. 7. Material flows obtained by image processing when the punch stroke increased from 0.9mm to 1.0mm:(a)*Cl*.1%; (b)*Cl*.5%; (c)*Cl*.15%.

It was expected that the area of rollover would agree with the sum of the amounts of material flow in the lateraldirection and clearance direction. Therefore, the relationship between rollover formation and material flow was investigated by measuring the amount of rollover by image processing. As shown in Fig. 8(a), the area (Ar) of rollover was measured from images obtained by the high-speed CCD camera during shearing. As shown in Fig. 8 (b), the amount (Al) of material flow in the lateral direction was calculated from equation 1 with the lateral displacement $D(y)$ obtained by image processing. $D(y)$ is variation of the displacement of sheet material along a straight line 3mm from the die edge.

$$Al = \int_0^t D_1(y)dy + \int_0^t D_2(y)dy \ , \tag{1}$$

where t is the material thickness.As shown in Fig. 8(c), the amount (Ac) of insufficiency of material in the clearance between the punch and die was calculated by multiplying the clearance (*Cl*) and the vertical displacement (Dv) of the bottom surface of the sheet material. The variations of Al, Ac, and Ar with the punch stroke are shown in Fig. 9. It was found that Ar is in good agreement with the sum of Al and Ac regardless of the clearance. Rollover is formed by material flow in the direction of the clearance and material flow in the lateral direction, which was confirmed experimentally using image processing. The amount of lateral material flow increased with increasing punch stroke in the initial shearing process. Then, the amount of lateral material flow hardly increased with increasing punch stroke in the later shearing process. The amount of lateral material flow decreased with increasing clearance.

3.5. Influence of clearance on rollover

The ratios of Al to Ar and Ac to Ar were calculated. The effect of the clearance on the ratio is shown in Fig. 10. The ratio of Al to Ar decreased with increasing clearance, whereas the ratio of Ac to Ar increased with increasing clearance. When the clearance was 1%, the ratio of Al to Ar was larger than that of Ac to Ar during the whole shearing process. On the other hand, when the clearance was 15%, the ratio of Al to Ar was smaller than that of Ac to Ar during the whole shearing process. Therefore, when the clearance is small, the material flow in the lateral direction strongly affects the rollover. In contrast, when the clearance is large, the material flow in the direction of clearance affects the rollover.

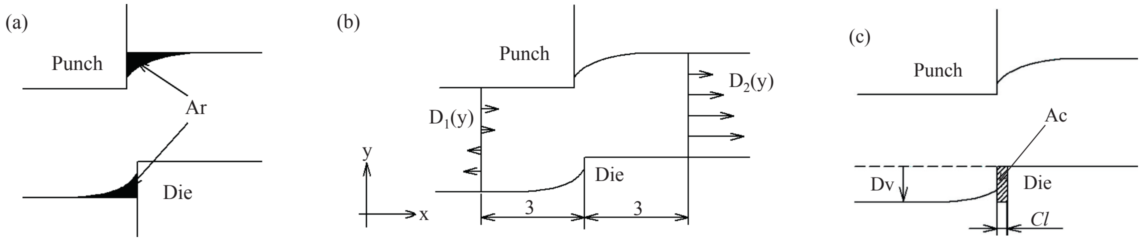

Fig. 8. Amount of rollover and measurement of displacement :(a) Amount of rollover; (b) Amount of material flow in lateral direction; (c) Amount of insufficiency of material between punch and die.

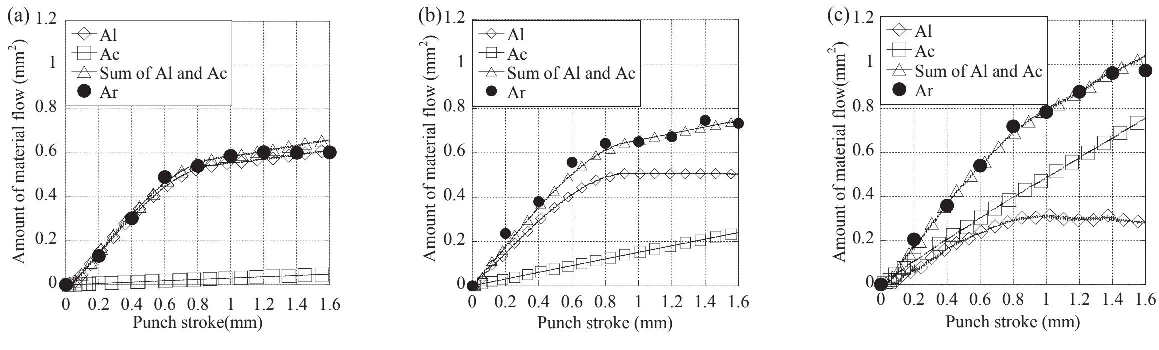

Fig.9. Comparison between measurements and calculated results :(a)*Cl.*1%; (b)*Cl.*5%; (c)*Cl.*15%.

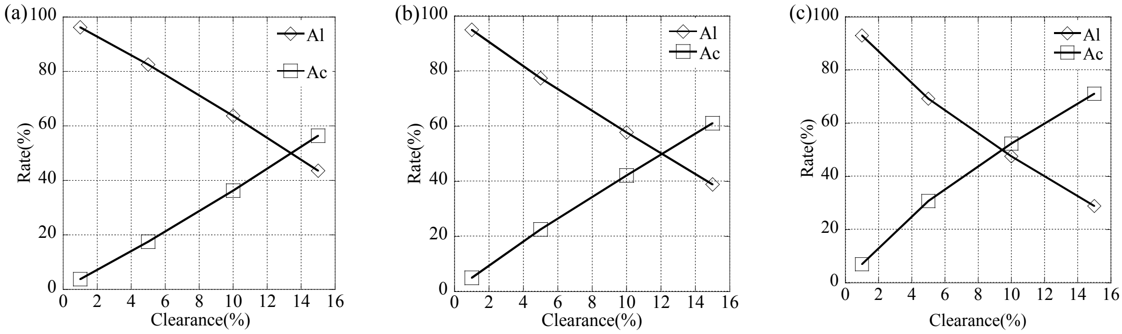

Fig.10. Influence of material flow in lateral direction and clearance direction on rollover :(a) Punch stroke 0.5 mm; (b) Punch stroke 1.0 mm; (c) Punch stroke 1.5 mm.

4. Conclusions

In this study, image processing was performed on the observed image to investigate the material flow and the influence of the clearance on rollover formation was discussed. The results obtained in this study were as follows:

(1) The rollover is formed by material flow in the direction of the clearance and material flow in the lateral direction, which was confirmed experimentally using image processing.

(2) The amount of lateral material flow increased with increasing punch stroke in the initial shearing process. Then, the amount of lateral material flow hardly increased with increasing punch stroke in the later shearing process. The amount of lateral material flow decreased with increasing clearance.

(3) When the clearance is small, the material flow in the lateral direction strongly affects the rollover, which was confirmed experimentally using image processing. In contrast, when the clearance is large, the material flow in the direction of clearance affects the rollover.

Clarifying the influence of the clearance on the formation of rollover will be helpful for setting the shearing conditions in precision shearing.

Acknowledgements

The authors would like to thank Mr. H. Yamamoto and Mr. K. Yonekubo for their help in the experiments.

References

Jimma, T., 1965. On the characteristics of shearing tests of sheet material. Journal of the Japan Society for Technology of Plasticity 6-52, 243-254.

Kondo, K., 1988. Consideration of accuracy improvements in blanking. Journal of the Japan Society for Technology of Plasticity 23-324, 21-25.

Ikushima, K., Iwasaki, I., Kondou, K., 1992. A new punching method for shear droop-free shearing. Journal of the Japan Society for Technology of Plasticity 33-381, 1172-1177.

Kasuga, Y., Tsutumi, S., Mori, T., 1977. On the shearing process of ductile sheet metals (Material flow in the deformation zone of the metal subjected to blanking with tools having closed contours), Transactions of the Japan Society of Mechanical Engineers 43-372, 3142-3149.

Maeda, T., Aoki, I., 1979. Slip behaviour of material on top surface of die in circular blanking, Journal of the Japan Society for Technology of Plasticity 20-218, 208-214.

Koga,N.,Kudoh,t., Murakawa, M.,1992. An application of visioplasticity to analysis of shearing phenomenon, Journal of the Japan Society for Technology of Plasticity 33-383, 1362-1367.

Takahashi, T., Aoki, I., 1996. Analysis of shearing by visioplasticity method using image processing (Proposed and verification of displacement measurement method usable for large deformations), Transactions of the Japan Society of Mechanical Engineers (C) 62-600, 3196-3201.

Aoki,I., Takahashi, T., 2003. Material flow analysis on shearing process by applying Fourier phase correlation method-analysis of piercing and fine-blanking, Journal of Materials Processing Technology 134, 45-52.